U. S. ARMY TEST AND EVALUATION COMMAND
BACKGROUND DOCUMENT

ROCKET SLED TESTING

1. INTRODUCTION

With the evolution of new theories, techniques, and materials which might be applied to weapons systems, ordinary laboratory tests may not be adequate to divulge all of the desired data. Data on parameters, such as linear acceleration sustained for periods of time, velocity, and aerodynamic effects of the type not attainable in the laboratory are often obtained from rocket sled tests.

The ability of a sled to generate dynamic loads of free flight tests and allow recovery of the test specimen, intact for further laboratory analysis, makes rocket sled testing a desirable way of accumulating test data.

To accomplish these objectives, this MTP presents some pertinent information about rocket sleds and their facilities. Sled tests are used to establish confidence in equipment under conditions of linear acceleration, shock, vibration, velocity, and aerodynamic effects, such as lift, drag, pressure, temperature, vibration and flutter, are typical of those which may be investigated. Other environmental parameters such as simulated weather effects may be added to increase the test conditions available.

Sled testing data may be obtained from captive tests of rockets, guided missiles, and model or full scale aircraft and their components. Aeroballistic tests of projectiles, rockets, and missiles fired or launched under simulated flight conditions may be accomplished. A wide variety of developmental materials, fuses, inertial guidance systems, and ejectable components, as well as inpact and damage tests, further describe types of testing available.

2. ROCKET SLED RANGES AND FACILITIES

Currently, there are four large general purpose tracks and approximately 20 special purpose tracks in the United States. The major tracks are located in the southwestern section of the United States where weather conditions, flat terrain and large unpopulated areas provide ideal locations for such facilities. Track facilities may be grouped according to their length. Long tracks are those that are 20,000 feet and longer. Medium tracks are 10,000 to 20,000 feet long and small tracks are less than 10,000 feet in length. These tracks are available to all Department of Defense Agencies and their contractors, to research organizations, and to private corporations developing products relating to national defense. Additional information on tracks may be obtained from the references listed in this MTP or by request from authorities at the installation of interest

2.1 MAJOR ROCKET SLED TRACKS

A list of the major tracks in t.e United States and their primary characteristics are listed in Table No. 1.

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Table I. Track Facilities (Sheet 1 of 2)

Track Data				Braking System		
Track and location	Length of Track Feet	Gauge inches	Rail Length feet	Type	Length in Feet	Description
NOTS, China Lake California Snort	21,500	56.5	50	Water	21,500	Located in through between rails
NOTS B-4 at	14,560 11,000	56.5 13	Varied	Sand Sand	4,560 4,560	Located between the rails
NOTS G-4 at	3,000	33 7/8	Varied	Retro Rockets if neces-sary		
AFFTC, Edwards Air Force Base, California	20,000	56.5	39	Water	6,000	Located between the rails
AFMDC, Holloman Air Force Base, New Mexico	35,071	84	39	Water	35,071	Located in through between rails, still pond height controlled by dams
HSRS, Hurrican Mesa, Utah	12,000	59.0625	39	Water & Mechanical	12,000	Located in through be-tween rails, mechanical arresting gear near muzzle end of track
Sandia Track, Sandia Co Alburquerque, New Mexico	3,000	56.5	39	Water and Chain	2,000	Located in through between rails
Aberdeen Ballistic Track, Aberdeen Proving Grounds, Aberdeen, Maryland	2,448	2	12			
Redstone Ballistic Track Redstone Ars. Huntsville, Ala.	600 at a 30° incline	56.5	Varied	No		
Redstone Expendable Horizontal Ballistic Track	897	56.5	39	Retro Rockets or Sands	897	Located between rails

Table I. Track Facilities (Sheet 2 of 2)

Track and Location	Elevation above Sea Level	Temp. Range at Track Site °F	General Application	Remarks
NOTS, China Lake California	2,100	Winter 20-85 Summer 50-110	High Speed, heavy duty	Ballistic and performance programs for IBM 709 Calculators available for all NOTS Tracks
B-4 at NOTS	2,100	Same as above	Marginal Design, Medium duty	
G-4 at NOTS	2,100	Same as above	Free flight terminal ballistic testing	
AFFTC, Edwards Air Force Base, Calif.	2,300	Winter 10-90 Summer 60-120	High Speed heavy duty	
AFMDC, Holloman Air Force Base New Mexico	4,000	Winter 5-95 AV 28-76 Summer 30-107 AV 53-94	High speeds, heavy duty, inertial guidance, aeromedical, deceleration impact	
HSRS, Hurrican Mesa, Utah	5,100	Winter 27-56 Summer 63-98	Over-the-cliff parachute and missile testing	
Sandia Track, Sandia Corp. Albuquerque, N.M.	5,400	AV. Min. 21 AV. Max. 92 Yearly	Impact testing, deceleration, parachute, high speed, medium duty	
Aberdeen Ballistic Track, Aberdeen Proving Ground Aberdeen, Maryland	18	Winter 10-70 Summer 50-100	Free-flight terminal ballistic testing	
Redstone Ballistic Track Redstone Ars Huntsville, Ala.	574 604	Winter 5-65 Summer 60-100	Missile launching	
Redstone Expendable Horizontal Ballistic Track	568	Winter 5-65 Summer 60-100	Fuze development testing, missile system component testing	Expendable and high explosive testing permitted

2.2 TYPICAL SLED AND OPERATION

In order to initiate a sled test program, a good knowledge of the construction of the test vehicle and its performance characteristics, as well as effects which the test conditions may produce, is highly desirable.

Figure 2, illustrates a typical sled. The sled supports and propels the test specimen. It may assume a variety of forms from an aerodynamically clean type to a simple all-purpose vehicle without fairing as illustrated in Figure 3. Sleds range in size from the small monorail type weighing a few hundred pounds to the large dual-rail type weighing many thousands of pounds. They are all attached to slipper similar to that shown in Figure 4 which follows the rail head and prevents derailing. Drag brakes and propulsion units are attached to the sled structure to pruduce the required sled performance. These general purpose sleds are usually available for leads of modest size and weight or for test requirements which are not considered too severe.

2.3 TYPICAL SLED TESTS

The following are typical areas in which testing may be accomplished to obtain data concerning aerodynamic acceleration, velocity, vibration, pressure and temperature effects:

a. Aerodynamic Studies - Investigations may be conducted on rockets, guided missiles, model or full scale aircraft, or airframe components under conditions that approximate free flight into the supersonic range.

b. Structural and Materials Testing - Numerous tests to determine the characteristics of materials and structural components under sled induced environments of acceleration and aerodynamic loading may be accomplished. Accerleration to induce forces on structural components may be programmed by the application of selected propulsion or braking procedures. Sled velocity for aerodynamic loading is dependent upon the track characteristics, as well as thrust, mass, and drag characteristics of the sled and its test specimen.

c. Aeroballistic Tests - Projectiles, rockets, or missiles may be fired or launched under simulated high speed conditions.

d. Escape Systems Tests - Seat ejection and jettison may be accomplished for almost all experimental and operational military aircraft. These tests are usually conducted at supersonic velocities.

e. Parachute Type Recovery Systems - The purpose of these tests is to evaluate and develop basic parachute materials and shapes.

f. Missile Components Tests - These tests may be conducted on engines, warhead fuze devices, inertial guidance systems, gyrostabilized mechanisms, and control systems conducted under sled produced sustained acceleration, vibration, and aerodynamic conditions.

g. Fuze Development Tests - Fuze functional characteristics are tested and evaluated. Impact may be accomplished under controlled conditions and the test results assessed upon inspection of the recovered hardware.

Figure 5, shows a typical fuze test.

h. Aircraft Damage Tests - Damage is caused by impact at high speeds with stationary targets. Such tests provide information of the load and strength of materials by studying the deformation of components. Figure 6, shows a typical impact test vehicle.

i. Aeromedical Tests - These tests determine the accelerations, decelerations, and wind blast effects on living subjects in conjunction with the protection devices used to reduce the undesired effects.

j. Rain Erosion Testing - For this test the specimen is carried through a simulated rainfall. Such tests are conducted to investigate the reliability of the radome of guided missiles and to determine the effect of rain erosion on various materials and nose cone configurations.

Figure 7, shows a typical rain erosion test configuration.

k. Unique Track Tests - Some unique track tests are discussed in Reference 2. Briefly, these tests are conducted to investigate the adequacy of homing type firing devices at high velocities (Mach 10). Figure 8, shows a typical attachment of a missile for a test ride or launching. Air-to-air missiles may be fired from sleds moving at Mach two and higher velocities. Unique track tests may also be conducted to study the effect of explosions occurring at high velocities. A type of unique track test that has successfully been conducted at Holloman AFB, New Mexico, is the recovery of artillery shells in an intact and undamaged condition so that the effects due to set-back or firing forces of the weapon may be evaluated.

2.4 MONORAIL VERSUS DUAL RAIL SLEDS

The choice of a monorail sled versus a dual rail sled (Figure 2) is one in which cost, reliability, and performance must be considered. A typical monorail sled is as shown in Figure 7. The monorail sled is usually easier to handle and transport. The combined cost of the sled and the propulsion system is less than the dual rail and extremely high velocities may be obtained. The monorail sled is ideal for use with small test specimens up to approximately 300 pounds and which do not present a problem in symmetrical loading.

The dual rail sled is used for testing items which cannot be handled by the monorail sled. The dual rail sled is capable of handling more weight, larger test specimens, and more instrumentation than the monorail sled. Also, with the dual rail sled the load distribution is not as critical. However, because dual rail sleds generally weigh more and have more drag than monorail sleds, they require more propulsive impulse to achieve the same velocity and acceleration rates.

Another configuration that should be considered is a combination of two sleds. This combination includes a pusher sled and a fore-body sled similar to that as shown in Figure 8. The pusher sled, as suggested by its name, is the vehicle which carries the propulsion units. It is used to push the fore-body

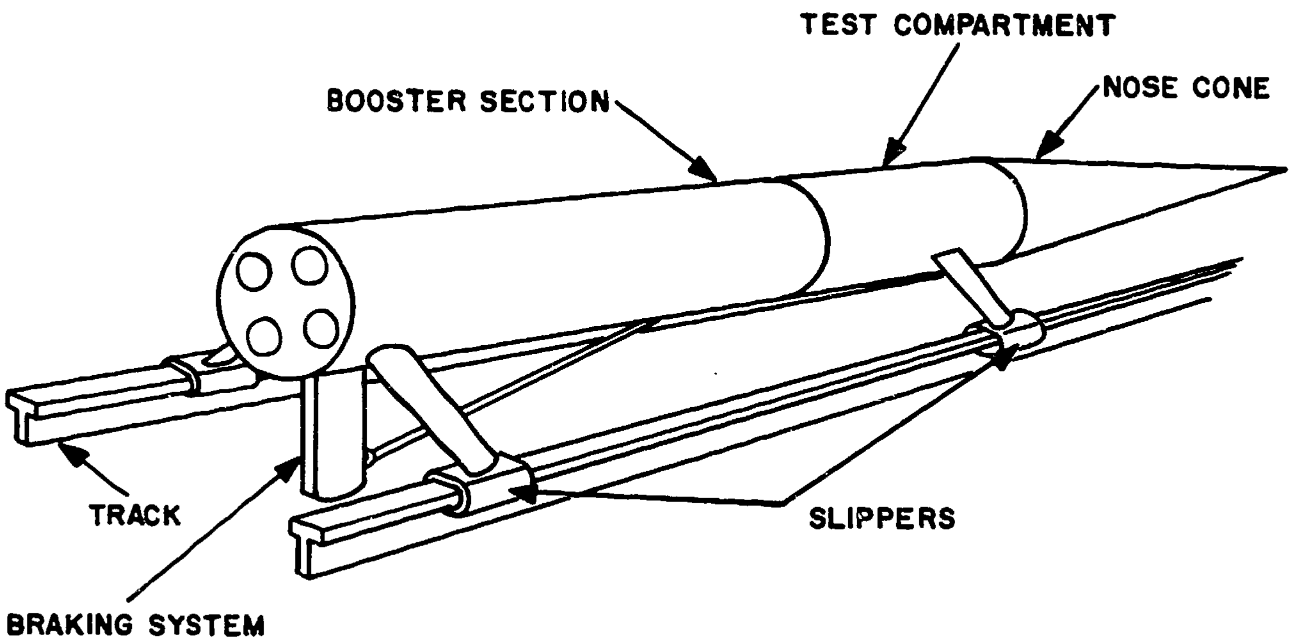

Figure 2. A Typical Rocket Sled

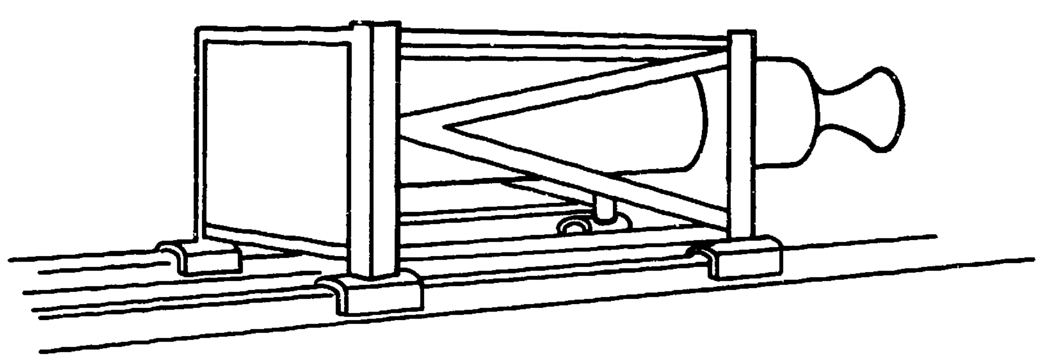

Figure 3. A Typical Sled Without Fairing

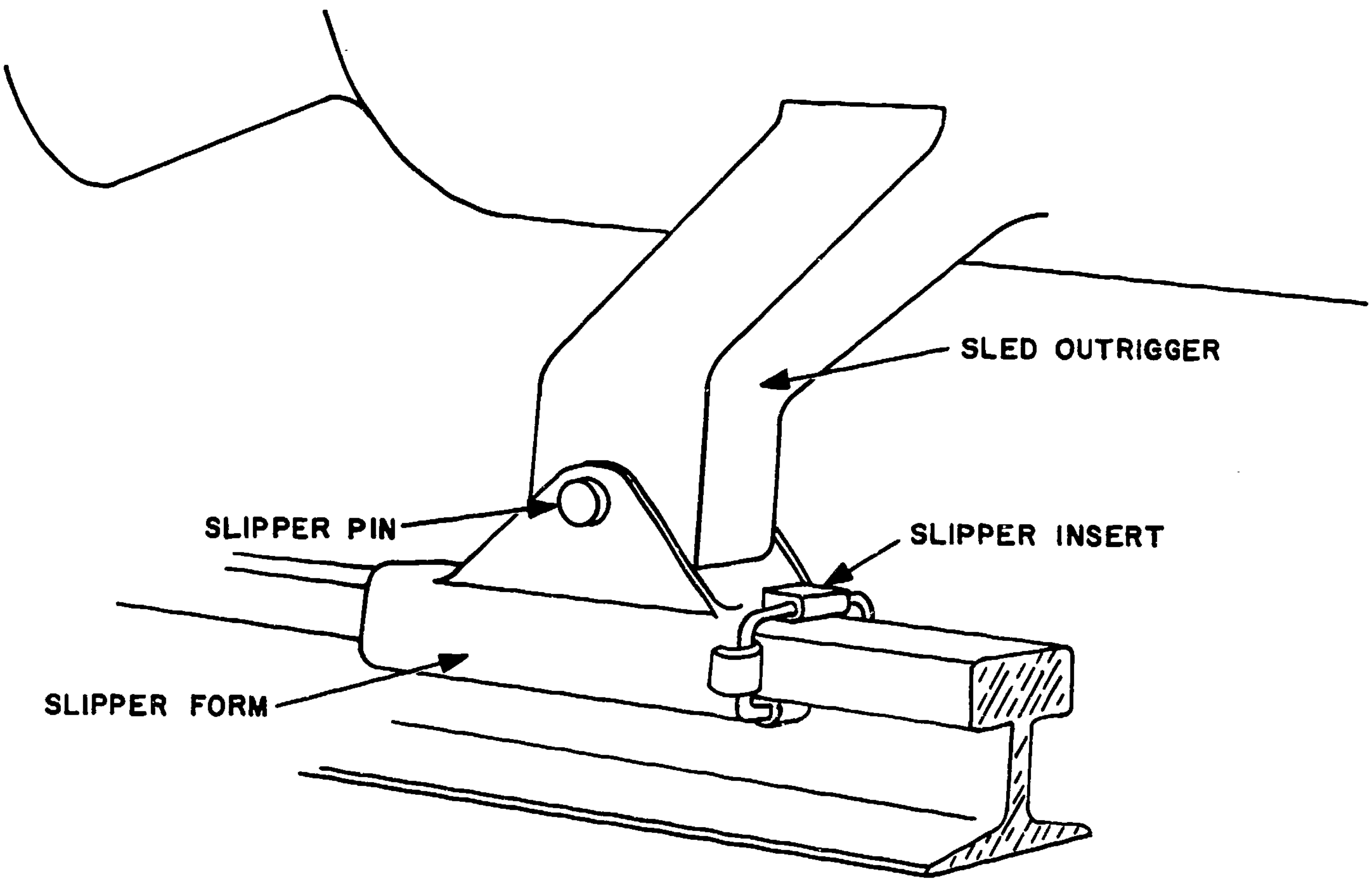

Figure 4. A Typical Slipper and Outrigger

sled upon which the test specimen is installed. This combination offers advantages not available in a single sled.

One advantage worthy of consideration is that of cost. If a pusher sled capable of producing the required test conditions is available at the installation, the problem of obtaining a sled to carry only the test specimen may be much simpler than to obtain a sled which must carry propulsion units as well as the test specimen. This sled combination is convenient when the test specimen size, configuration, and weight prohibit its installation on a single sled equipped with propulsion units, or when the cost of a specially designed single sled is prohibitive.

The pusher sled combination offers flexibility which may be desirable under some conditions of operation. The ability to separate the sleds

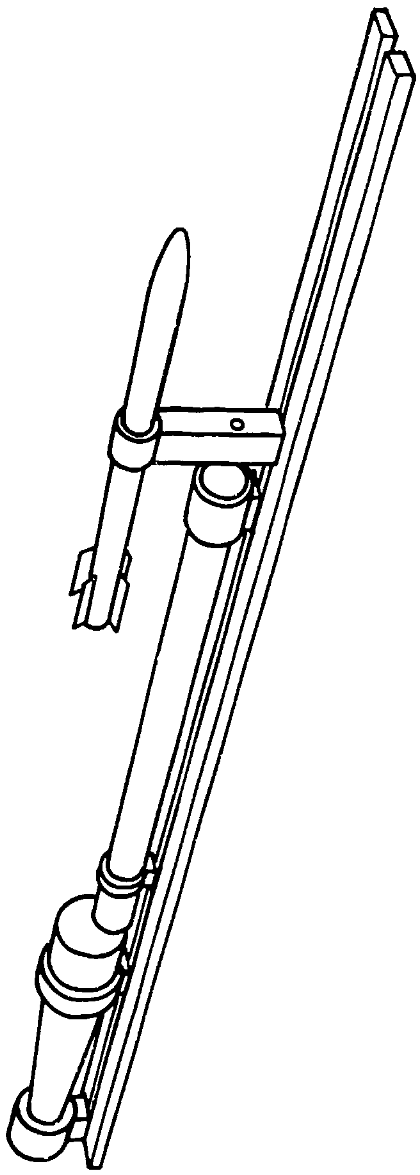

Figure 5. Terminal Ballistics Fuze Test

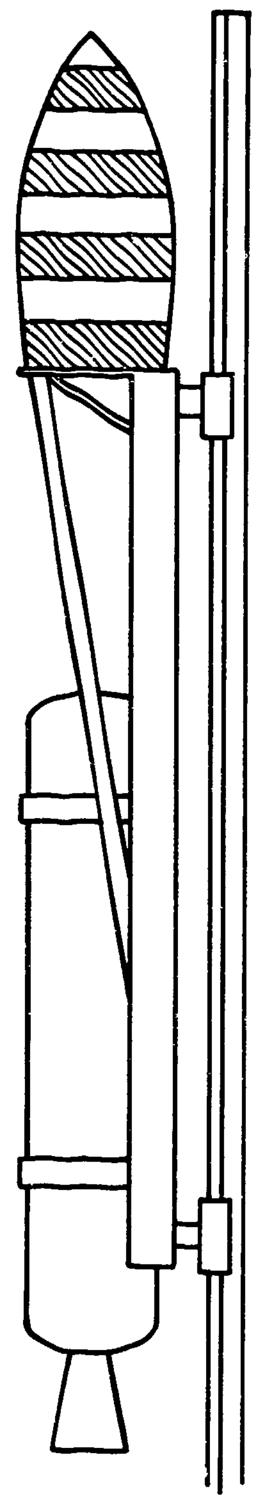

Figure 6. Inpact Test Vehicle

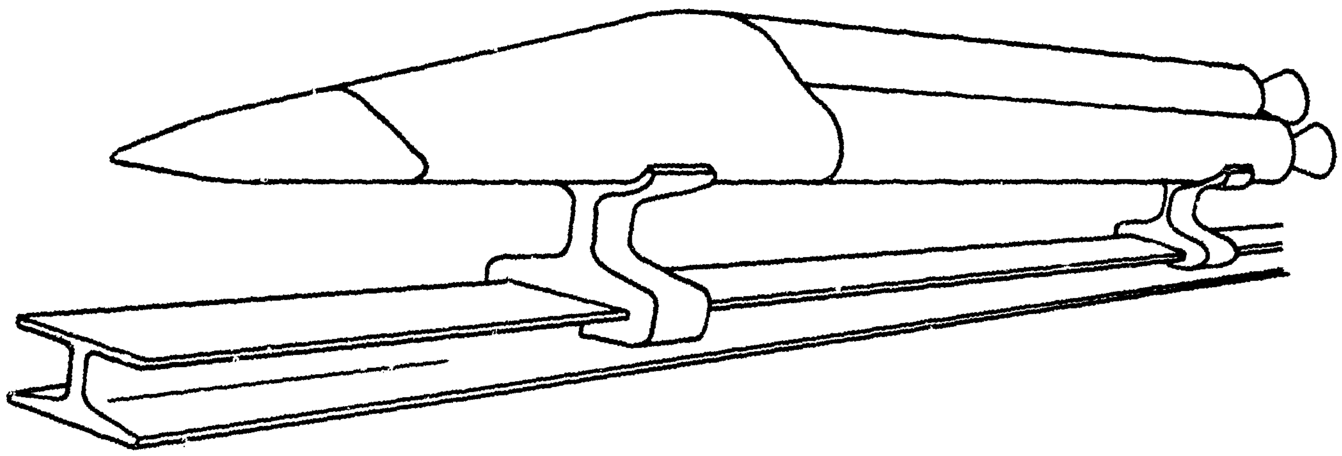

Figure 7. A Typical Monorail Sled

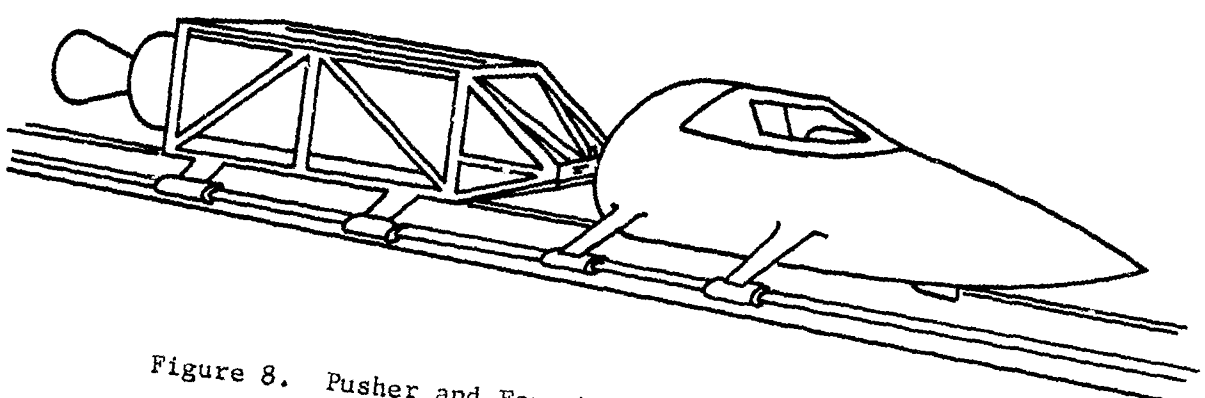

Figure 8. Pusher and Fore-Body Sled Combination

enables servicing of the propulsion units and the test specimen at different locations.

The propulsion system to be used in the program must be considered at the time the sled is selected. A wide selection of boosters are available for use in sled test applications. However, there is also a wide variation in cost. If the test program consists of a number of sled runs, the economics of the program should be investigated considering all acceptable sled propulsion unit combinations that are available. Figure 20, illustrates a comparison of vehicle design as influenced by the required sled runs.

2.5 ROCKET SLED TEST INSTRUMENTATION

Accurate and versatile instrumentation is indispensable for collecting reliable information resulting from sled tests. Data requirements of the test will determine the specific instrumentation to be selected. This instrumentation, however, will consist primarily of electronic and photographic apparatus.

The electronic instrumentation facilities at the test tracks are divided into four major categories. These are:

2.5.2 Radio Telemetry

The telemetry in general use is an FM/FM frequency multiplexed system which is capable of providing up to 14 channels of information transmitted over a single carrier frequency. Another telemetry system is the pulse code modulation (PCM) system which offers accuracies greater than those available through FM/FM systems.

2.5.3 Sled Position and Velocity Systems

For the accurate measurement of velocity and sled position, the data obtained from a sled mounted accelerometer used in conjunction with space-time data are fed into a computer which processes the data and computes the velocity and position. Other systems may use a sled mounted magnet which generates a signal when it passes over a track mounted coil. Pulses are sent to a receiving station and recorded on film by continuous strip cameras. A time base is recorded at the same time. Velocity profiles are computed from these data.

2.5.4 Timing Systems

Timing systems are necessary to determine and define the time relationship of special events. Pulses at various rates are transmitted over radio links to the instruments requiring time correlations.

2.5.5 Wire Telemetry Systems

Wire connected telemetry equipment may be used to transmit data on

the phenomena occurring during the first few feet of sled travel, such as acceleration and transient loads at starting.

2.5.6 Photography

Motion and still photography has an important role in supersonic track testing. It can slow down and permanently record actions in a form easily assessed and analyzed. Most of the data requirements of a test may be met by locating ground photographic instruments off-track or on overhead mounts above the track. However, some requirements may be met only by mounting a photographic instrument on the sled itself to record the events occurring on or near the test vehicle. Such photographic recorders should be, in many cases, specially designed to withstand the extreme physical environment of the test sled. The metric photographic instruments are particularly suited to the collection and recording of space-time data. The accuracy of the position data, normally provided by the permanent metric cameras, is ± 0.0005 times the slant distance from a station. The surveillance photographic instruments provide engineering surveillance, time history, attitude, deflections in yaw, pitch, and roll, and slow motion studies of high speed phenomena. Still cameras ranging from 35 millimeter (mm) through 4 x 5 speed graphics and up to extremely large copy cameras may be used for documentary coverage.

2.5.7 Data Considerations

A primary consideration in support requirements is that of data. The ability of an installation to obtain data of the type and accuracy required should be determined early in the planning phase of the program. Reliable instrumentation, timing, communications, and programming signals should be available. Data monitoring and collection facilities are indispensable. Major installations are equipped to allow rapid inspection of data recorded on magnetic tape and automatically handled through data processing facilities. Data reduction and computation services in which data are presented in various forms may be found to be beneficial in allowing time and effort of responsible personnel to be concentrated where required. Also, the installation of transducers and the associated instrumentation on the sled must be considered. The effect of the sled produced environment on instrumentation is a primary consideration in sled testing. Equipment that is sensitive to sled produced perturbations of shock accerlerations, vibrations, aerodynamics, and thermal effects must be installed so that adequate reliability may be obtained. Specially designed isolation mounts may be required to protect the test specimen against exposure to severe shock and vibration.

3. SLED PERFORMANCE

The two main forces acting upon the sled in various combinations and magnitudes is thrust and braking.

3.1 THRUST FORCE

The thrust force represents the total accelerating thrust acting on the sled. For sled performance calculation, sled thrust is often considered to be constant during the burning time of the rocket, although it is seldom actually constant. The thrust may be obtained by using the thrust-versus-time curves at the temperature of firing supplied by the manufacturer of the booster. From these curves, an average thrust level may be determined which may be used in the computations with reasonable results. Figure 9, is a typical curve used to obtain the magnitude of thrust level.

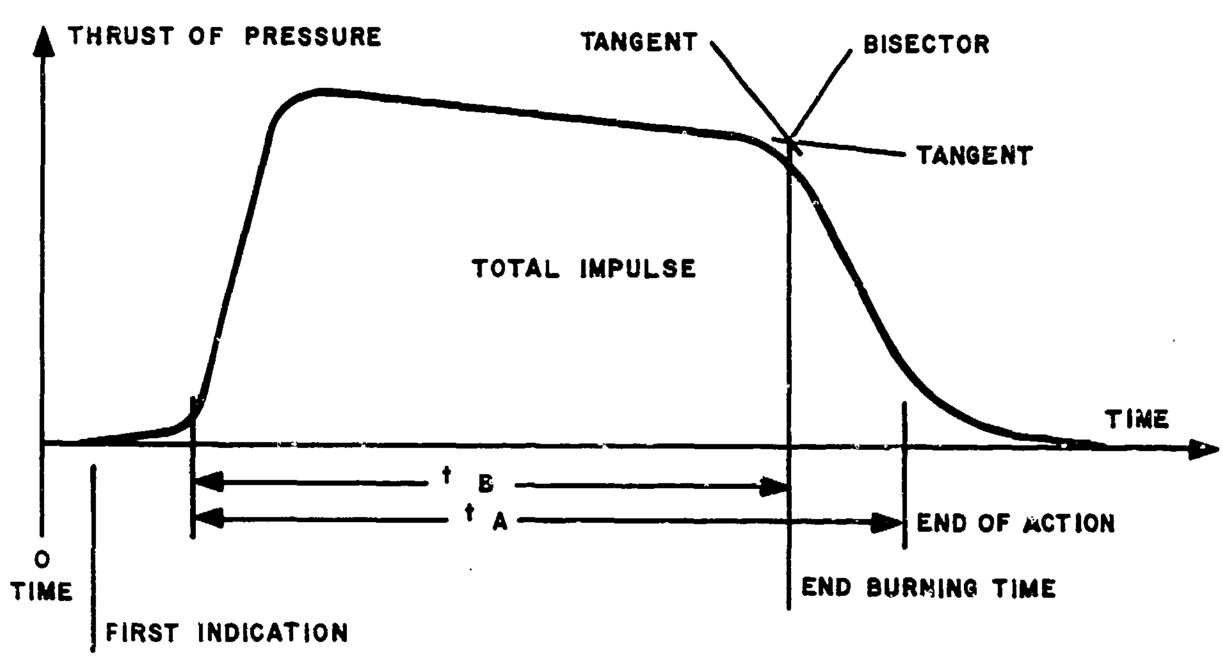

Figure 9. Typical Thrust Curve

A burning time approximating the duration of the thrust of the booster should be obtained. It is defined as beginning when the chamber pressure has risen to 10 percent of its maximum value and ending when the pressure begins to drop sharply near the end. This point is found as shown on Figure 6. The thrust during the burning time is then found by dividing the total impulse of the motor by the burning time. The total impulse is defined

as the area under the thrust time curve between the points corresponding to the time where the pressure has risen to 10 percent of its maximum value.

Either solid or liquid propulsion units can be used to provide thrust for the sled. The choice of a propulsion system depends upon a number of factors, and is best determined after the test requirements are known. It also depends on payload weight and volume, desired performance, time available for sled design and construction, and the number of tests programmed. The number of runs required has a great bearing on the choice of propulsion systems. In general, liquid propellant costs for a single run will be approximately five percent of solid propellants costs.

3.2 SLED BRAKING

Since exis'ing high speed tracks are not long enough to allow the test vehicle to coa to a stop, the vehicle braking system is an important consideration in the design of recoverable rocket propelled vehicles. Figure 10, shows the types of braking systems commonly used on rocket sleds. Variable drag is frequently used to control test acceleration conditions. Through the programming of drag, a wide variety of acceleration versus time data may be obtained. This means of controlling acceleration makes available a combination of flexibility and accuracy which is often used to produce conditions not attainable by propulsion systems. The braking systems most commonly used in sled testing are water brakes, sand brakes, and airbrakes. Retrorockets, as a means to brake sleds, has been generally regarded as undesirable due primarily to the high cost. The choice of the sled brake system is often limited by track braking facilities that are available. It should be noted, however, that an air brake or parachute brake may be used with any sled regardless of the track braking facilities. The designer is often faced with the problem of designing a brake that is capable of providing a specific deceleration level or duration. The aerodynamic drag effect of the brake during acceleration must also be considered. These effects should be kept at a minimum. The following paragraphs briefly discuss the more common types of sled braking systems:

a. Water Brakes - Recovery of most large sleds is by use of water brakes. Water braking is accomplished through the use of water contained in a trough between the track rails. A scoop or water brake is suspended on dual rail sleds so that it extends down into this trough, picks up the water, turns it through an angle, and ejects it, thus transferring energy from the sled to the water and bringing the sled to a stop. The braking force is a function of the amount of water picked up, the velocity of the sled, and the geometry of the scoop. Since the velocity of the sled and the geometry of the scoop are controlled, it only remains necessary to control the amount of water passing through the scoop in order to control the water braking force, and thus the sled deceleration. The probe brake, the vertical momemtum exchange brake (VME) and the horizontal moemntum/exchange brake (HME) are examples of successful water brakes. The probe brake is desirable because of its light weight,

simplicity, ease of fabrication, little chocking of airflow under the sled, and low cost. However, it has disadvantages such as the low application of braking force and the water spray inpingement effects which may be undesirable. The VME brake is more difficult than other brakes to incorporate in the sled structure; however, they are usually lighter in weight per unit of braking force. This brake also possesses aerodynamic disadvantages which tend to induce divergent oscillation in the sled structure during the braking action. Sleds using VME brakes are usually very rigid. The HME brake is easy to incorporate in sled design since it is usually carried externally. Chocking problems are greater in this type of brake than in the VME; however, the oscillation problem is not as pronounced. Reference 1 of this MTP discusses momentum/exchange brake designs and the basic design equations.

b. Sand brakes - Sand braking is accomplished with a solid probe, similar to the probe used with water brakes, which is extended down into the sand located between the tracks. Sand brakes may be used successfully at speeds up to 700 fps.

c. Airbrakes - Airbrakes may be designed to change position during a sled run so that they present minimum aerodynamic drag until they are needed to assist deceleration. When applied, these brakes increase the drag coefficient by presenting more surface to the airstream. They may be placed at various locations on the vehicle.

d. Other Braking Systems - Parachute braking is sometimes used for sled program; however, their use is generally limited because the velocity required for opening the chute is approximately 700 fps (in some cases it is as high as 1,000 fps). Other special brakes are the hydraulic and hydromechanical braking systems that seize projections from the sled. The Sandia Corporation track in Albuquerque, New Mexico, includes a heavy chain backup brake system. A long anchor chain is extended along the water trough which is picked up by a hook under the sled.

Since the chain is picked up link-by-link, drag is increased incrementally. The chain system is usually combined with a conventional water braking system at this installation. A hydro mechanical arrester system has been installed at the Hurrican Supersonic Research Site, Hurricane Mesa, Utah. With this system the sled picks up cables which are attached to pistons floating in water-filled tapered tubes. As the pistons are pulled through the tubes, in the direction of decreasing diameter, the pressure differential across the pistons and the dynamic resistance of the water flowing around the piston dissipate the kinetic energy of the moving sled.

4. SPECIAL PROBLEMS

The three major problems encountered in sled testing are reducing the shock and vibration environment, minimizing sled wear, and avoiding sled structural fatigue.

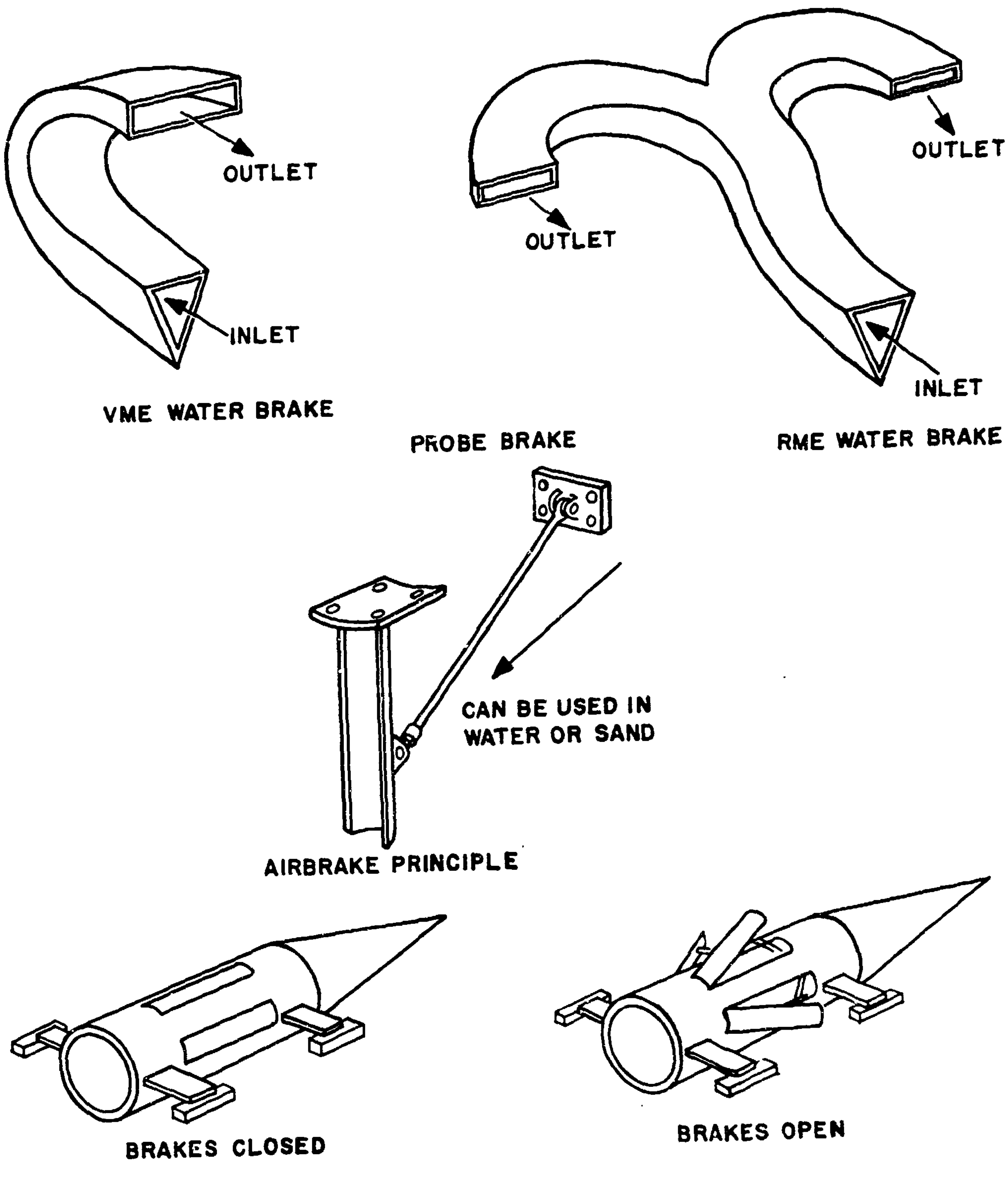

Figure 10. Types of Common Sled Braking Systems

4.1 SHOCK AND VIBRATION

The shock and vibration that is experienced in a test specimen may have several sources of excitation. Mechanical excitation may be due to the operation of the propulsion system, operation of the unit under test, and inputs from the sled slippers. The first two sources of mechanical excitation are obvious. However, the slipper mechanical excitation forces are those due to track irregularities, rail joints, misalignment, slipper clearances, and slipper chatter. The vibrations from forces due to propulsion, braking and the unit under test will vary in intensity depending upon the hardware and configuration of the equipment being used.

4.2 WEAR

High speeds and long test runs coupled with the increase in sled weights and dynamic forces have resulted in wear at the bearing or restraining connection between the sled and rail. Lubrication and gas bearing are two methods that have been considered to reduce the wear at the slipper to rail interface. Also, melt lubrication may be achieved from a molten layer of metal that behaves as a lubricating film between the sliding surfaces. This layer is formed when the frictional heat generated between sliding surfaces is sufficient to melt the slipper surface.

4.3. STRUCTURAL FATIGUE

Fatigue is the failure of a structure caused by repeated load tests. Fatigue and stress concentration are frequently considered with equal importance as a dangerous combination. Fatigue causes the failing stress to be reduced considerably below values which might be calculated or determined from routine strength tests, while stress concentration may cause local stresses to be considerably greater than nominal calculated values.

5. TEST DATA

All test results, both raw and processed, should be properly marked for identification and correlation to the respective test. Also a detailed discussion of test conduct including deviations from test procedures, problems encountered and any other information that may be considered of value to those reviewing the test. Specifications that will serve as a model for a comparison of the actual test results should be made available.

6. EVALUATION

Evaluation will consist of analysis of all records generated during the conduct of the test, as recorded by test instrumentation, and visual observations. The test results may also be compared to the applicable specifications set forth by the testing agency, and previous rocket sled tests that were conducted using similar types of sled, tracks and units being tested.

GLOSSARY

1. Arming: Completing the circuitry of the boosters preparatory to firing.

2. Baffle: A wall or plate used to prevent the sloshing of liquid fuel in tank or to retard the flow of water in a water braking trough.

3. Ballistic Trajectory: The acceleration, velocity, and space time history of a sled.

4. Boundary Layer: The layer of air next to an airframe, distinguishable from the main airflow by distinctive flow characteristics of its own.

5. Breech: The loading and firing end of a track.

6. Carriage: The basic supporting structure of a sled.

7. Coasting: That portion of the sled trajectory during which time there is no rocket thrust or braking forces other than air drag and track friction.

8. Conical Cylinder Body: The external configuration of a sled that consists of a conical forward end and cylindrical afterbody.

9. Coutdown: The period of time allotted for preparation before the firing of the vehicle. The countdown also applies to the oral announcement of remaining time before firing.

10. Dam: A flangible plate inserted in the water brake trough to hold the water at a specific depth.

11. Damping: The attenuation of an oscillating motion by the dissipation of energy.

12. Deployment: The action of releasing a parachute or other device. Parachute deployment is that portion of a parachute operation occurring from the limitation of ejection to the instant that the lines are fully stretched, but prior to inflation of the canopy.

13. Drag: That aerodynamic force which opposes the forward movement of the sled.

14. Fairing: The auxiliary structure used to reduce the aerodynamic drag of a sled.

15. Ground Interference Effect: The aerodynamic forces caused by a build-up of pressure between the track ground plane and the sled.

16. Hydraulic Damper: A hydraulic device used to attenuate the effect of conditions, such as mechanical shock.

17. Hypersonic Speed: That velocity above Mach five.

18. Igniter: A device used to start the reaction of the rocket propellant.

19. Interference Effect: The aerodynamic forces produced as result of the interaction of air flow around two surfaces in close proximity.

20. Mach Number: A ratio formed by division of the sled vehicle speed by the velocity of sound in the free air about the vehicle, or a ratio of the local velocity of air flow at a point (p) divided by the velocity of sound in the stream at point (p).

21. Outrigger: The portion of a sled extended externally from the carriage to which the slippers are attached.

22. Phasing: The sequential firing of a rocket propulsion unit or a test vehicle.

23. Performance Curve or Performance Profile: A plot of calculated or measured values which indicate sled performance, such as velocity, acceleration, distance, and/or thrust versus time.

24. Programming: The presetting of thrust and acceleration devices to achieve a desired trajectory.

25. Rail Roughness Load: The load caused by vibration, bounce, and rail deviations. These conditions are compensated for by applying a rail roughness load factor through the center of gravity of the structure under analysis. This factor is used in both the lateral and vertical directions.

26. Slipper: A mechanism attached to the outrigger of the sled which supports the sled and secures it to the track rail(s).

27. Squib: An electrically energized explosive charge.

28. Staging: The sequential firing of sled boosters. The stages are designated by the order of firing.

29. Subsonic Speed: The velocity which extends to a Mach number of 0.8

30. Supersonic Speed: The velocity in the Mach number range of 1.2 to 5.0

31. Thrust Plate: That portion of the rocket sled on which the booster thrust reacts.

32. Transducer: A device which converts shock or vibratory motions into an optical signal that is proportional to a parameter of the experienced motion.

33. Transonic Speed: The velocity in the Mach number range of 0.8 to 1.2

34. Vertical Wedge Configuration: A wedged shaped sled with the leading edge in the vertical plane.

35. Water Trough: A trough of water used in conjunction with a sled mounted water brake system to decelerate the sled.

36. Weirs: The submerged damming strips used to govern the level of water in the water brake trough.

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